1470

IRRIGATION UNIFORMITY & WATER USE EFFICIENCY in KERN COUNTY

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The goal of the CALFED Water Use Efficiency Program, as stated on page 2-1 of the Draft Water Use Efficiency Program Plan (DWUEP, June 1999) is as follows:

"The Water Use Efficiency Program will assure high efficiency through programs that benefit local water users, districts, regions and the state."

This document rightly states that there are several definitions of 'water use efficiency' (WUE), and that it would be inappropriate for the CALFED process to look only to the "traditional definition of physical efficiency ... the ratio of water consumed to water applied." But it is my opinion that CALFED has not yet sufficiently grappled with this basic definition, much less the broader context.

At issue is the ability of CALFED to facilitate the accurate quantification of potential agricultural water conservation for providing increased water supply to the state as a whole. This estimate now stands at 5.7 to 6.4 MAF for the state (Table 4-5, DWUEP, June 1999) and 1.2 to 1.4 MAF for the Tulare Lake Region alone (Table 4-10a, DWUEP, June 1999). The validity of these numbers hinge on assumptions regarding the amount of crop evapotranspiration (ET) and the ability to significantly improve the uniformity of applied irrigation water to meet the ET requirement. As the Kern County Irrigation Management and Agronomy Farm Advisor with the University of California Cooperative Extension I would like to offer some comments regarding ET and irrigation uniformity in Kern County.

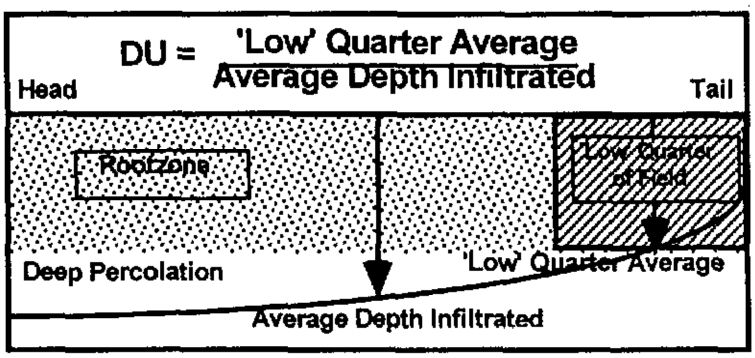

Figure 1. Illustration of the calculation of distribution uniformity (DU) for surface irrigation.

The final uniformity and efficiency of an irrigation system is impacted by a wide variety of factors. Distribution uniformity (DU) and Irrigation efficiency (IE) are the two terms we use to describe the performance of an irrigation system. Figure 1 is a vertical view of water penetration down a furrow after a surface irrigation event, and in this case would represent about a 70% DU. Micro irrigation (drip, etc.) and other pressure systems, such as sprinklers, have DU's that are determined by the mechanics of the system and not by the irregularities of the soil. In these systems DU is the lowest one-quarter of pressure points and emitter flows divided by the average flow for the whole system.

A theoretically 'perfect' irrigation is one that refills 87.5% of the rootzone (the average requirement of the low quarter). This assumes that some deficit irrigation can be tolerated on 12.5% of the field. Thus, a field that is irrigated on a schedule that never stresses the crop will have an Irrigation Efficiency that equals or is less than the DU. For more than a decade, Mobile Irrigation Labs across the state have been doing irrigation system evaluations on grower fields that provide a snapshot of DU during a particular irrigation event. These results have been reported in the latest "California Water Plan Update" (DWR Bulletin 160-98). At face value, the numbers imply that DU's across the state are below potential for most systems, and that substantial water could be saved by improving the management of existing systems and converting surface irrigation to micro systems. The Draft Water Use Efficiency Program Plan (June 1999) appears not only content with this assumption, but glosses over the issue of irrigation system limitations when calculating "potential" savings by

1470(2)

simply saying that the final 30% of the savings estimate is "non-conservable" due to technical/engineering limitations (Attachment A: Determination of Potential Agricultural Conservation Savings). The lack of clarity and justification in these assumptions is unacceptable. For the Tulare Lake Basin, applied water is listed as 9.2 MAF, system losses as 0.6 MAF with stated ET demand at 6.9 MAF. **This gives an 80% water use efficiency for farm applied water using CALFED numbers.** CALFED gives no justification as to why an additional 70% of that remaining 20% margin can be conserved; especially when current DU estimates for the state imply that an 80% regional WUE is not possible given current irrigation uniformity. Research work and years of production irrigation management in Kern and Kings Counties have convinced me that our current, one shot methodologies for evaluating irrigation uniformity (especially for surface and sprinkler systems) substantially underestimates the DU and seasonal water use efficiency. This means that the margin for improvement is not a large as CALFED currently assumes.

Figure 2 shows the averages (and standard error) of 710 irrigation system evaluations conducted by the Pond-Shafter-Wasco Mobile Irrigation Lab for two six-year periods from 1988 to 1993 and again from 1994 to the end of this season in 1999. Even though water costs have nearly doubled in some cases over the last six years there has been little impact on improving countywide average uniformity. (Actual numbers are given in Table 1.) The take-home message is that under typical management, furrow, border, linear, micro spinners, fixed jets and drip systems in the southern San Joaquin Valley average 80 to 85% uniformity. All of these systems had one or more evaluation DU's in excess of 90% and other evaluations with less than 60% uniformity.

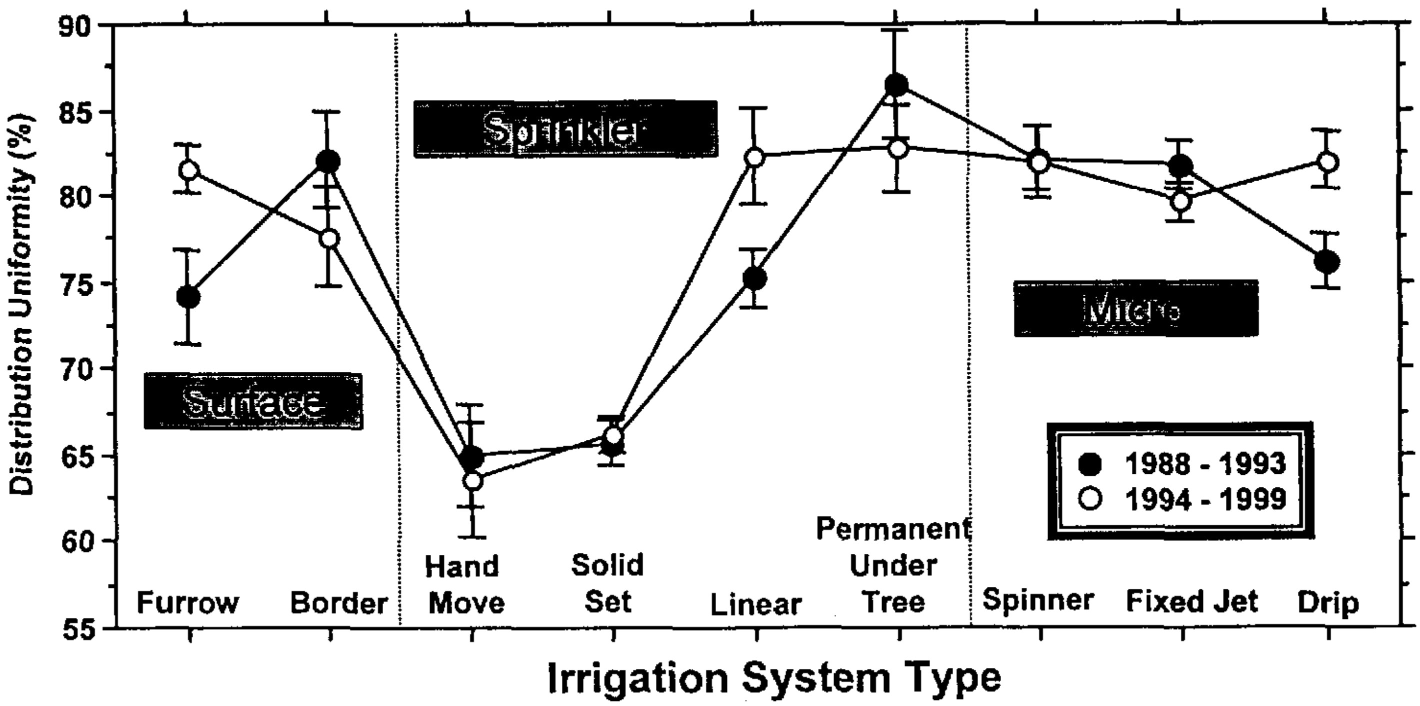

Figure 2. Mean DU and standard error for various irrigation systems conducted over 12 years by the Pond-Shafter-Wasco Resource Conservation District Mobile Irrigation Lab.

Even though permanent undertree sprinklers show the highest average distribution uniformity (DU) it does not mean that they are necessarily the most efficient system. Many of these orchards have been plagued with runoff and poor yields. (The high DU is the uniformity of flow rates between individual sprinklers, covering two to four trees or an area of 24' by 48'. For solid set, hand-move and linear sprinklers, typical for carrots and potatoes, DU is the uniformity of the droplets of water caught in a grid of 5" diameter catchcans. Slight changes in the wind can make a big difference in DU.) Permanent undertree sprinklers were considered the optimal system for trees twenty-five years ago, but there have been almost no additional systems of this type installed over the last two decades in Kern County, even though almond acreage has nearly doubled to 90,000 acres. This system wastes a tremendous amount of water to evaporation and deep percolation in young orchards. Weed problems and inefficient nitrogen fertigation compound the problem. Fixed micro-jet systems (as evidenced by the more than doubling of evaluations for 1994-1999, Table 1) and double-line drip have been the systems of choice followed by border strip surface irrigation with a tail-water return system.

The effective rootzone is the key to the area that should be monitored as to the uniformity of water applied. Drip system DU's are determined by the uniformity of one emitter compared to another. This often underestimates the 'effective DU' when there are multiple emitters per tree or vine, while in the case of undertree sprinklers the DU is probably overestimated.

Table 1. Number of evaluations, means, standard deviations, and standard error for various irrigation systems conducted over 12 years by the Pond-Shafter-Wasco Resource Conservation District Mobile Irrigation Lab.

	DU Stats for 1988 - 1993				DU Stats for 1994 - 1999			
	Count	Mean	Std. Dev.	Std. Error	Count	Mean	Std. Dev.	Std. Error
Furrow	34	74.09	15.52	2.66	33	81.58	8.40	1.46
Border	29	82.00	15.18	2.82	30	77.63	15.83	2.89
Hand Move	24	64.88	14.38	2.94	10	63.50	10.51	3.32
Solid Set	66	65.67	10.77	1.33	78	66.24	9.09	1.03
Linear	39	75.15	10.60	1.70	8	82.25	7.96	2.81
Under Tree	13	86.46	11.29	3.13	8	82.75	7.30	2.58
Spinner	9	82.11	5.56	1.85	18	82.00	8.97	2.11
Fixed Jet	49	81.78	9.81	1.40	109	79.63	12.06	1.15
Drip	83	76.13	14.43	1.58	70	82.03	13.93	1.67

The major deficiency with current evaluation methodology and reporting of irrigation uniformity in California is that we generally depend on a one-time DU number generated over a few hours to represent the net efficiency of a system that may run for more than 1000 hours over the season. The engineering potential of drip, microsprinkler/jets and linear move systems can approach 95%, but I have personally evaluated systems that were 95% one week and 70% the next due to a pressure regulator that temporarily froze or some algae that reduced the inlet pressure to one or two hoses. These are common and *unavoidable* occurrences.

A three-year, detailed study of season-long irrigation, nitrogen leaching and yield uniformity in carrots was recently completed by a team of UC researchers in Kern County. Catchcan evaluations were conducted over the entire set duration (8 to 14 hours depending on lateral spacing) instead of the usual two to four hour catch time most often employed by the Mobile Labs. Not only did the 78.6% average DU of 44 separate evaluations exceed the 66% average reported in Table 1 by more than ten percentage points, but the normalized **season-long DU averaged 86.2%** (see Table 2). The uniformity of all root yields corresponding to the areas of catchcan evaluation averaged 85.8% (Fertilizer Research and Education Program Proceedings, CDFA 1997-1999).

In addition to the inadequacy of our current DU estimates, the ET assumed for much of our high-production acreage in Kern County is also too low. I have personally monitored many blocks of almonds and pistachios that use more than 48 inches of water as opposed to the 33 to 42" generally assigned to these trees when doing district water balances. Many of these orchards, as well as alfalfa, cotton and corn end up deficit irrigated during the season either because of inadequate scheduling or soil sealing. For these fields, and I

1470(4)

would estimate the acreage to be easily 200,000 acres, the irrigation efficiency is 100%. **There is no more blood in the turnip!**

Table 2. Typical irrigation set times, sprinkler and carrot root yield distribution uniformity (DU) characteristics for intensively sampled grids under varying solid-set sprinkler lateral spacings.

Lateral Spacing (ft)	Typical Irrigation Set Time (hrs)	Applied Water per Set (in)	[1]Total Irrigation for Season (in)	Mean Root Yield for Grided Plots (ton/ac)	[2]Mean Normalized Sprinkler DU (%)	Yield DU (%)	[3]R^2 for Normalized Sprinkler and Yield DU	[4]Mean Evaluation DU (%)
SPRING 1996								
33.3	8.5	2.21	25.65	35.95	84.1	84.3	0.047	*80.6ab
40.0	10	2.16	25.63	37.35	81.6	81.5	0.114	78.1a
46.7	12	2.23	26.08	36.03	89.9	85.4	0.073	86.0 b
SPRING 1997								
42.0	10	2.41	30.94	*38.80a	87.6	89.3	0.054	82.0
48.0	12	†2.64	34.32	32.48 b	84.2	85.2	0.042	76.2
FALL 1997								
36.0	9.5	†2.67	19.64	35.91	84.2	87.2	0.063	75.2
42.0	11	2.35	17.96	34.58	90.8	85.6	0.124	77.4
45.0	12	2.40	17.27	34.81	87.6	88.0	0.054	71.8

[1] Rainfall negligable for fall 1996 and spring 1997. Fall 1997

[2] Normalized precipitation for each grid element was computed as a percent of the average for each *for each element of all sprinkler evaluations times total precipitation for the season is used to compute*

[3] R^2 values are for a second order polynomial regression of yield and normalized precipitation by

[4] Equals the mean of computed DU values from individual evaluations. Does not

*Numbers with different letters are *significantly different*

† Pressure excessive due to cooperator error when

CALFED's current carte blanche assumptions of agricultural water conservation savings are totally unacceptable, especially for Kern County. There are certainly areas within the County and the larger Tulare Lake Basin where particular irrigation systems and farm operations could be substantially improved, but this is a small percentage of the total basin acreage. Finally, substantial groundwater overdraft has long been documented in the basin as a whole. Since we are a closed system with no natural drainage outlet how can this be possible if growers are "wasting" the CALFED estimated 1.2 MAF every year through poor irrigation efficiency?

In conclusion, it is imperative that the CALFED process not gloss over these issues. YES, they are very difficult to deal with from the technical side, without even considering the politics. YES, it is very costly to develop the kind of data that I have presented here and may be beyond the scope of the present CALFED process. YES, the Tulare Lake Basin must be broken into sub-regions if a credible estimate of water savings is to be made. YES, it is my belief that when this is done there will be little if any agricultural water savings that can be justified for the region as a whole if we are to continue mitigating groundwater overdraft. CALFED **cannot** mandate "Additional consequences of inadequate water use efficiency (to growers)... *through the urban certification process (Section 2.2.2) and the Agricultural Strategic Plan (Section 2.2.1).*" (Pp. 2-2, Draft Water Use Efficiency Program Plan, June 1999) without better technical justification then is currently offered.